PRELIMINARY

INSTRUCTION MANUAL

SD-101 DYNAMIC ANALYZER

SPECTRAL DYNAMICS CORPORATION OF SAN DIEGO

1162 Morena Boulevard
San Diego 10, California
BRowning 6-2331

June 15, 1962

Introduction to:

SPECTRAL DYNAMICS CORPORATION OF SAN DIEGO

NEW, IMPROVED

DYNAMIC ANALYZER - MODEL SD-101A

The Model SD-101A is very similar to the earlier Model SD-101. The following changes were incorporated into the SD-101A:

A - FRONT PANEL

1. Meter Damping - The screwdriver adjustment on the front panel allows the operator to select additional meter damping. This is used in random testing.

2. Phase Adjust - The screwdriver adjustment located on the front panel allows the operator to phase normalize the input to output phase or the phase from channel to channel in multi-channel systems. This adjustment is the same as used on the SD-1012 Tracking Filters.

3. Overload Indicator - The overload indicator is the same as that used on the SD-1012. It indicates when the input signal has exceeded the crest factor of the instrument, thus telling the operator to either reduce his input amplitude or select a higher range. The crest factor of the instrument is 4 to 1.

B - REAR OF CHASSIS

1. Rear Connectors - The rear connectors have been changed to XLR type connectors and relocated. This is a much better type connector and is more standard in industry.

2. 100 Kc Output - The 100 Kc I.F. has been brought out to the rear of the chassis to be used in phase applications at low frequency operation.

C - INTERNAL CHANGES

1. Printed Circuit Board Holders - The printed circuit board holders have been improved to provide better cooling and easier maintenance.

2. Low Pass Filter - The low pass filter in the filtered signal output circuit has been changed to a plug-in type filter of improved design. This improves performance and maintenance.

3. Demodulator - The demodulator for the filtered signal output has been changed to a plug-in type unit. This also improves performance and maintenance.

4. Output Amplifier - The output amplifier design was improved.

5. Filter Oven Circuit - The ovens are now operated from AC rather than DC which decreases the warm-up time required to place the instrument in operation.

6. Other Improvements - Many other internal changes have been made that improve the performance and they will be explained in later material.

The above information should familiarize you enough to enable you to demonstrate our new, improved SD-101A Dynamic Analyzer.

NOTE:

1. The new instruction and maintenance manual will be available about February 1, 1963.

2. Delivery of the SD-101A is off-the-shelf, or one (1) week.

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Block Diagram - SD-101 Dynamic Analyzer
Schematic - SD-101 Dynamic Analyzer
Applications Brochure - SD-101 Dynamic Analyzer

SECTION I - GENERAL

1.1 UNPACKING

The Model SD-101 Dynamic Analyzer is shipped fully assembled in a polystyrene carton which protects the instrument against all normal shipping hazards. To determine possible damage during shipment of the instrument, the procedures given below should be followed:

(a) Place the carton upright on the floor and inspect the exterior, making note of any visible damage.

(b) Remove and retain all forms and invoices attached to the carton by the carrier.

(c) Unseal the top portion of the carton and remove.

(d) Lift the instrument out of the carton and place it on a work bench or other flat surface.

(e) Inspect the exterior of the Dynamic Analyzer carefully, noting all visible damage.

(f) The Dynamic Analyzer may now be checked for functional operation by following the procedure outlined in Section II.

1.2 CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the dispostion to be made of the equipment and arrange for repair or replacement. Include Model Number and Serial Number when referring to this instrument for any reason.

SECTION II - OPERATION

2.1 SPECIFICATIONS

Frequency Range	2 - 25,000 cps
Useful Range	1 - 30,000 cps
Dynamic Range	Meter Ckt 55 db Filtered Signal Output 50 db Linear DC Output 30 db
Linearity	Meter Ckt ±3% of F.S. DC Output ±3% of F.S. Filtered Signal Output ± 0.5 db
Sensitivity	1 mv - 1000 v full scale
Input Impedance	1 megohm
Tuning Signal	0.5 v (rms) minimum input required (sinusoidal) with less than 5% distortion
Selectivity	Accommodations are provided for two plug-in crystal filters. Typical bandwidths are 2.0, 5, 10, 20 and 50 cps. The shape factor (60 db/ ± 3 db bandwidth) of each filter is nominally 4/1.
Calibration	Internal Reference
Tracking Rate	The unit may be swept at rates in excess of 500 cps/sec when used as a tracking filter. A PSD analysis using a 20 cps filter from 10 cps to 3 kc, may be accomplished in one minute
Outputs	1. Recorder: 0 - 1 vdc into 10K 2. Filtered signal: Adjustable for 10 v rms maximum into 100 K load
Power	105 - 125 vac, 50/60/400 cps. 120 watts approximately. 230 vac by special order
Input/Output Availability	All input and output jacks on the front panel are paralleled with connectors on rear of unit
Size	7" high, 19" wide, 14" deep Shipping weight: 37 lbs

2.2 PRELIMINARY OPERATION CHECKS

A. Meter Mechanical Zero

Check the meter mechanical zero. If the pointer does not rest directly over the zero with the power off, proceed as follows: A stable adjustment can only be made when the direction of pointer travel is opposite to the direction of rotation of the adjust screw. The adjusting screw may be turned in either direction, but a good way is to turn the screw clockwise until the pointer swings up-scale and then starts to swing down-scale towards zero. Continue turning the screw clockwise until the pointer (now moving to the left) is directly over the zero mark. If you go too far, continue turning the screw clockwise until the pointer is again traveling down-scale toward zero. Tap the meter lightly to avoid any friction in the movement from giving a false indication of zero.

B. Carrier Switch

Check to see that the carrier "INT/EXT" toggle switch located on the rear of the unit is in the "INT" position.

C. Installation of Filters

Loosen the Camloc fasteners, holding the top cover in place by turning the fasteners one-half turn counterclockwise. Rotate cover back (cover is rear-hinged), exposing the interior of the equipment. Plug in the crystal filters in the octal sockets marked "F1" and "F2" located on top of the chassis. "F1" and "F2" correspond to the front panel filter selector, Positions "1" and "2", respectively. Narrow or broad filters can be installed in any desired order.

D. Insertion Loss Correction Potentiometers

The filter insertion loss correction potentiometers are multi-turn trimpots located behind the front panel on the filter selector switch. The left-hand potentiometer adjusts the output of filter "F1" - the right-hand potentiometer adjusts "F2". The insertion loss is higher in the narrower bandwidth filters; therefore, the following is the setup procedure used to normalize the filter insertion loss:

1. Apply power to unit and turn power switch to "STANDBY". Allow approximately 15 minutes for warm-up before proceeding.

2.2 PRELIMINARY OPERATION CHECKS - Continued

2. Turn "RANGE" and "MULTIPLIER" selectors to "CAL" position. Turn power switch to "ON".

3. Select filter position which selects narrowest filter installed.

4. Adjust the "FREQUENCY" control for a peak indication on the output meter.

5. Turn the insertion loss potentiometer for a meter reading of "7". If potentiometer fails to provide sufficient adjustment to obtain a meter reading of "7", obtain the maximum reading and adjust the "GAIN" control to obtain the reading of "7".

6. Select the broader filter and turn the corresponding insertion loss potentiometer to obtain a meter reading of approximately "7" on the meter.

7. Repeat step #4 and re-adjust insertion loss potentiometer for an exact reading of "7" on the meter.

8. Recheck narrow and broad filters being careful to re-peak the frequency control each time a different filter is selected.

NOTE: Before operating the SD-101, study the Block Diagram, Schematic & Application Brochure.

2.3 OPERATION

A. Filter Center Frequency Alignments and Sensitivity Cal

On calibrate, the units sensitivity is compared against the voltage output of an internal zener diode reference operating at the line frequency. The filter center frequency alignment relative to the tuning frequency, as well as the sensitivity calibration, is performed as follows:

1. Turn on power and allow unit to warm up.

2. Turn "RANGE" and "MULTIPLIER" selectors to "CAL" position. This operation connects the internal reference to the input of the Analyzer, and provides an internal tuning signal to the unit.

2.3 OPERATION - Continued

3. Select desired filter.

4. Adjust the frequency control for a peak indication on the output meter.

5. Adjust the "GAIN" control for an indication of "7" on the output meter.

   REMEMBER: Repeat above procedure when selecting a different filter bandwidth. Some filters will have their center frequencies close enough to omit re-peaking the meter each time a different bandwidth filter is selected. Nevertheless, the above is a good habit to develop.

6. Apply the tuning frequency and data signal to their proper front or rear connectors. Adjust the tuning signal level control for centerline on the tuning meter.

THE INSTRUMENT IS NOW READY & OPERATING

2.4 SETTING THE "RANGE" AND "MULTIPLIER" SWITCHES

Always start any measurements with the "MULTIPLIER' switch in the "1.0" position. Rotate the "RANGE" switch to obtain an up-scale reading. The purpose of this is to utilize the full dynamic range of the instrument. The filtered signal output is only affected by the "RANGE" control, and this means the signal-to-noise ratios are primarily dependent on the "RANGE" setting.

/ CAUTION /

This input level should not exceed the range control volts rms. Higher values can overload the input amplifier.

The unit will withstand crest factors (peak/rms) of approximately 2.5 to 1 when operating with the maximum rms input. This ratio goes up proportionally as the input level is less than the range (rms).

2.4 SETTING THE "RANGE" AND "MULTIPLIER" SWITCHES - Continued

EXAMPLE: Range switch set at 1V rms - input level .5V rms.

The input amplifier will now handle crest factors of 5 to 1. This becomes a factor when dealing with random or sine random type of input signals. However, clipping the large transient peaks of a random signal will not appreciably affect the accuracy of measurement.

2.5 MAKING RELATIVE MEASUREMENTS

When observing relative levels on the meter, the front panel "GAIN" control can be used to adjust the reading over an 11db range. Adjust for a full scale reading with the "MULTIPLIER" on the "1.0" position. Re-establishing the instrument calibration on an absolute basis can be accomplished by repeating the procedure of Paragraph 2.3.

2.6 CALIBRATION OF INTERNAL REFERENCE

To re-calibrate the instruments internal reference against a standard voltmeter, the following procedure is used:

1. Set the "RANGE" at 1V and the "MULTIPLIER" at "1.0" and select narrowest filter in unit.

2. Connect an external signal of 1V rms from an oscillator to both the "SIGNAL INPUT" and "TUNING INPUT". Adjust the Tuning Signal Meter for a centerline indication.

3. Adjust the "FREQUENCY" control for a peak indication on the output meter.

4. Adjust the "GAIN" control for a full scale meter indication.

5. Switch the "RANGE" and "MULTIPLIER" to "CAL" and the meter should indicate "7". If not, open the top cover of the instrument and adjust the potentiometer marked "R7 CAL ADJ" located on the top left side of the chassis until a meter reading of "7" is obtained. Repeat the procedure to be sure of proper adjustment, and lock "CAL ADJ" potentiometer, observing the meter reading with the "RANGE" and "MULTIPLIER" switches in "CAL" to make sure this reading does not change when re-locking potentiometer.

2.7 TYPICAL OPERATIONAL TROUBLES ENCOUNTERED

SYMPTOM	PROBABLE CAUSE AND REMEDY
1. No Power	Blown fuse - Replace with 2 amp., 3 AG slo-blow. If this fails, remove bottom cover & check for possible short circuit in B+ lead. B+ leads are all the red leads, with exception of leads from the transformers.
2. Distortion of Filtered Signal Output	a) Too high or too low level of tuning signal. Re-adjust the center line on tuning amplitude meter. b) Distortion or noise in the tuning signal. Remedy: Source of noise or distortion being fed to Tuning Signal Input. c) Filter bandwidth too wide for frequency of operation. d) Input signal level to Analyzer too high, overloading input amplifier. Reduce level at input. e) Range switch in wrong position.
3. Excessive noise in Filtered Signal Output	Input level too low, thus not using full dynamic range of filtered signal output. Range switch in wrong position.
4. Frequency response poor at low frequency	Load impedance on filtered output too low. Increase to 100 K or more.
5. Irregular meter fluxuation at low frequencies	Filter bandwidth too wide for frequency of operation. Use narrower filter.
6. No Tuning Meter indication	Carrier "INT-EXT" switch in wrong position. Tuning amplitude potentiometer in wrong position.

If any additional operating difficulties are encountered, contact the nearest Spectral Dynamics' representative, or the factory.

APPLICATIONS

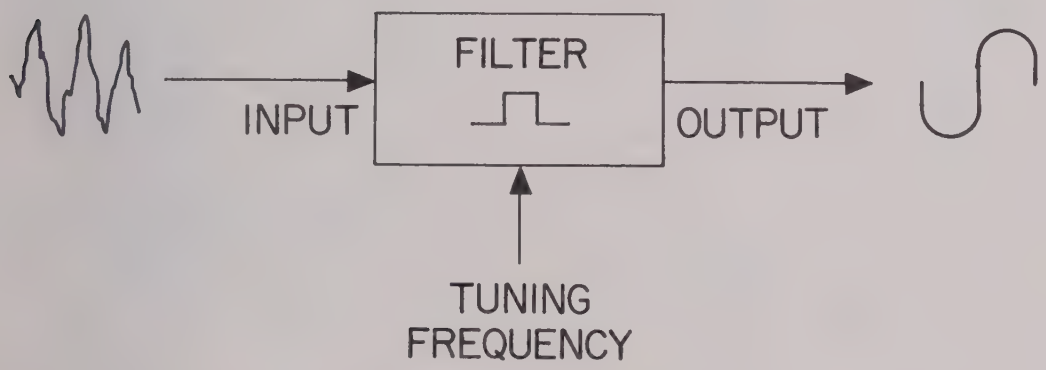
DYNAMIC ANALYZER

SPECTRAL DYNAMICS CORPORATION OF SAN DIEGO

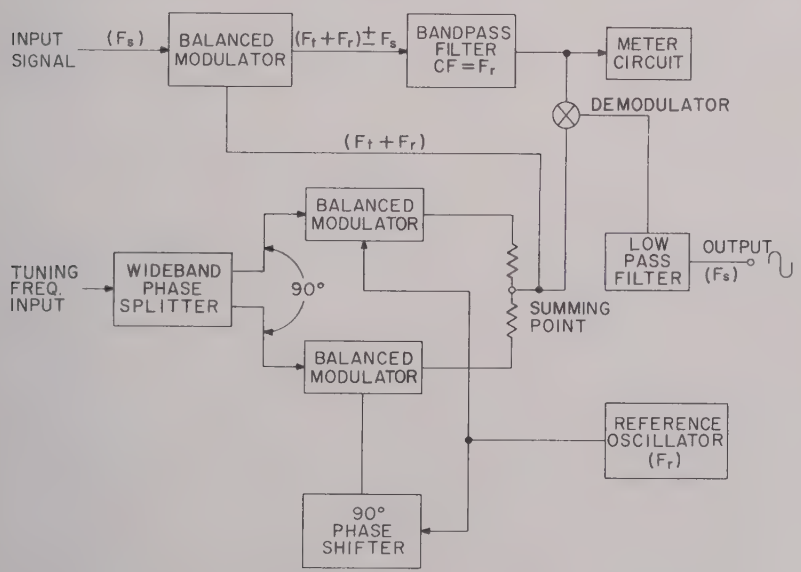
1162 Morena Blvd., San Diego 10, California BRowning 6-2331

IDEALIZED CONCEPT OF THE DYNAMIC ANALYZER

The Spectral Dynamics Corporation DYNAMIC ANALYZER is a newly developed multipurpose instrument offering exceptional application versatility in the fields of vibration, acoustical and electrical analysis and measurement. The Analyzer is essentially an inherently frequency-tuned bandpass filter. The center frequency of the instrument is continuously and precisely tuned to track the frequency from an external source. It is a completely frequency-tuned system and does not depend on an internal servo or utilize frequency to DC conversion for its unique operation.

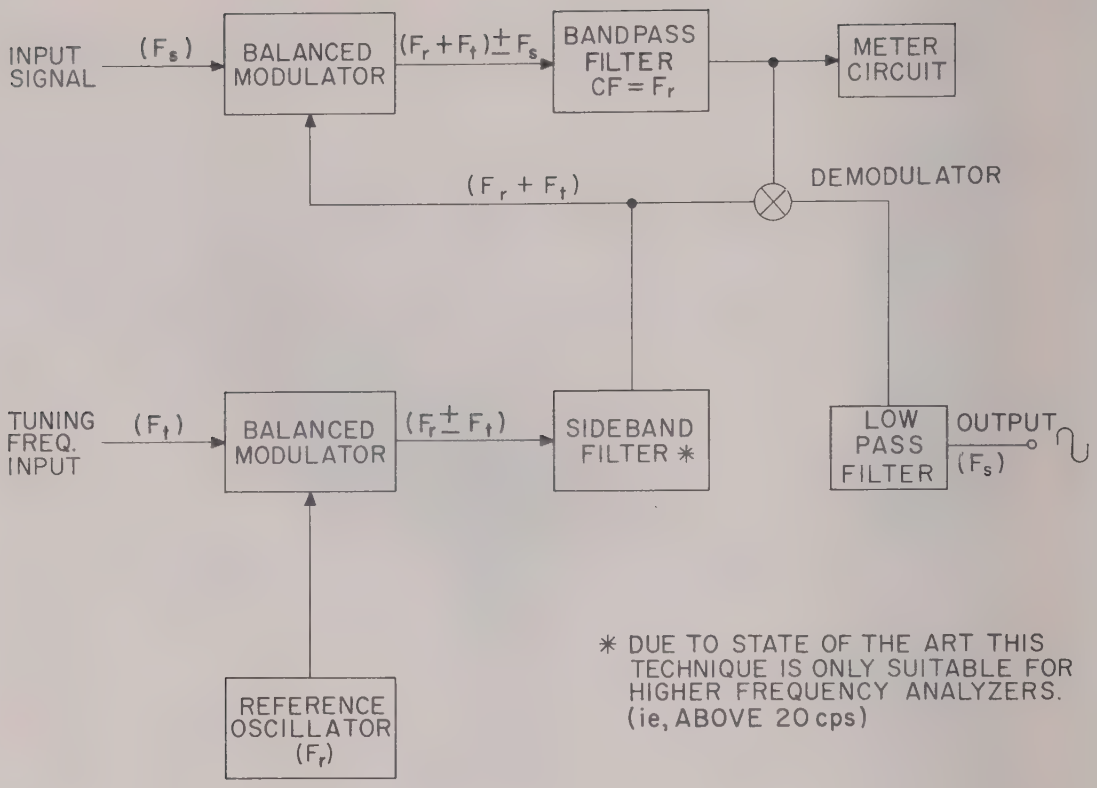


TECHNIQUES BY WHICH THIS IS ACCOMPLISHED:



Method 1 - This technique is useful to below 1 cps.

Patent No. 3,018,439



Method 2

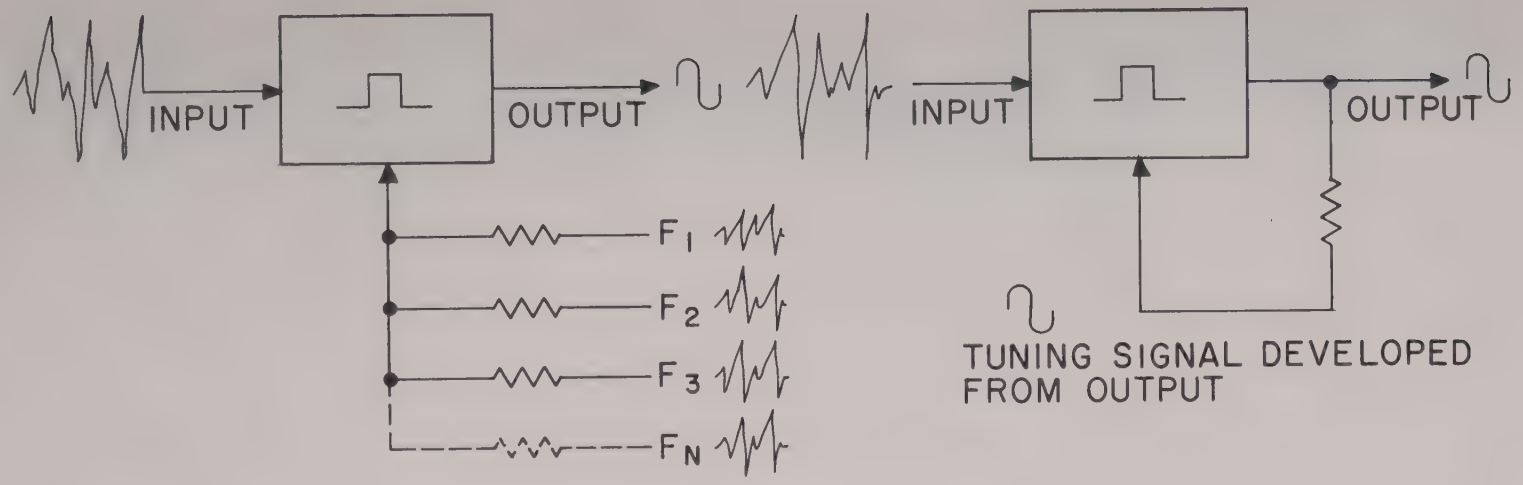
APPLICATIONS

The following applications, employing the frequency-tuned bandpass filter, are presently being studied. They are shown in block diagram form to illustrate the wide variety of applications that are possible.

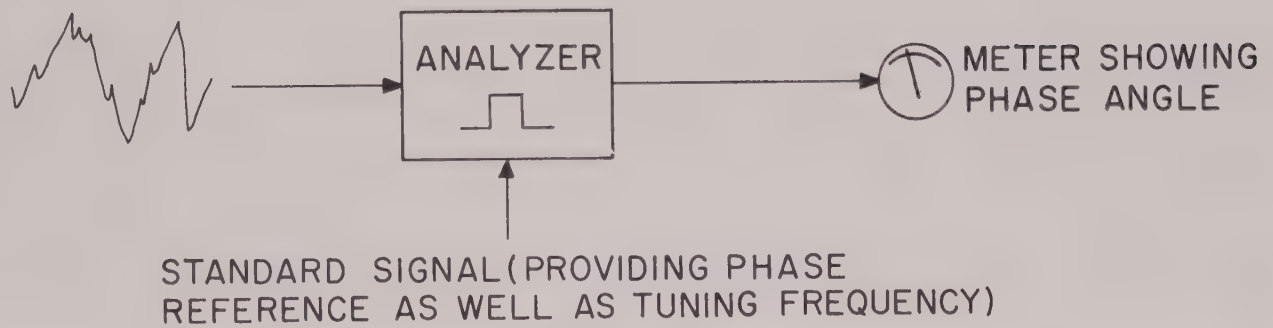
Primary concentration to date has been in the field of jet engine analysis. Applications in the fields of Television, Communication, Radar, Sonar, Guidance and Control Systems, Data Transmission, Target Tracking, Aircraft Approach Control, and any of the fields other than purely Vibration Analysis, are presently being studied. Undoubtedly there would be many applications in the fields mentioned above, and should the reader have a particular application in mind, he should feel free to call on our engineering staff to discuss and to help work out the application in detail.

1. BEING TUNED TO SEVERAL FREQUENCIES AT ONCE

2. SELF TRACKING FEATURE

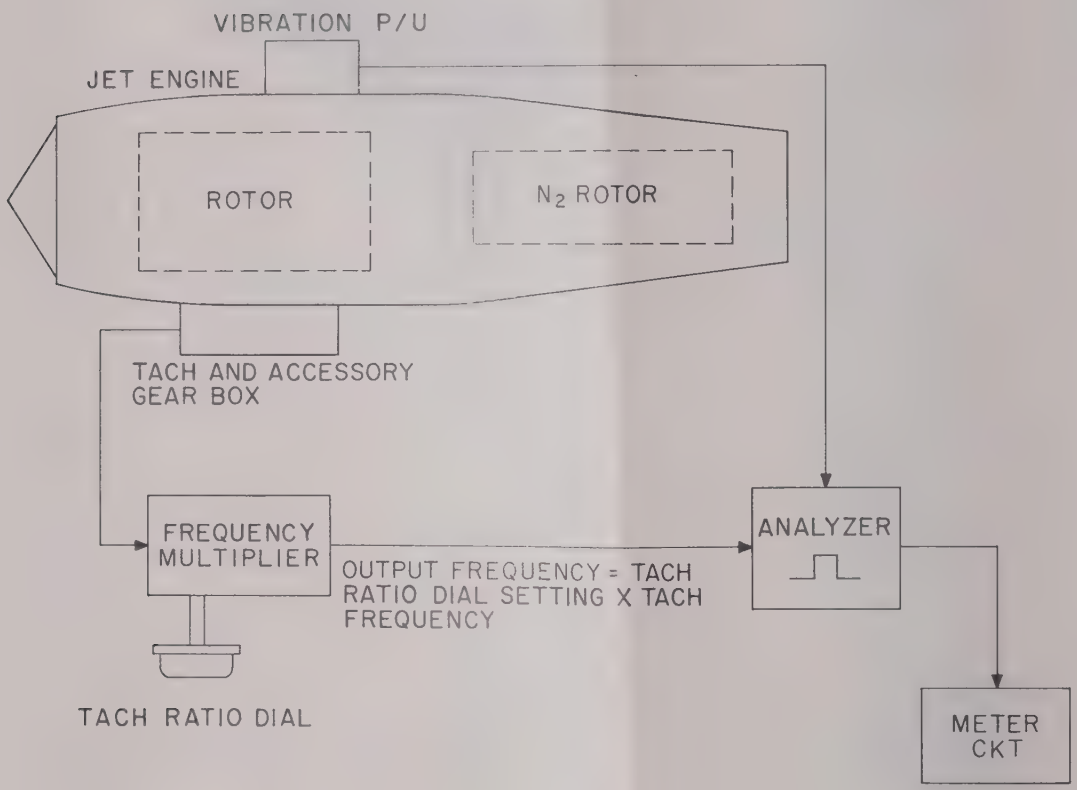


3. PHASE MEASUREMENTS



I. VIBRATION ANALYSIS of rotating machinery, i.e., jet engines, motors, turbines, gyros, etc.

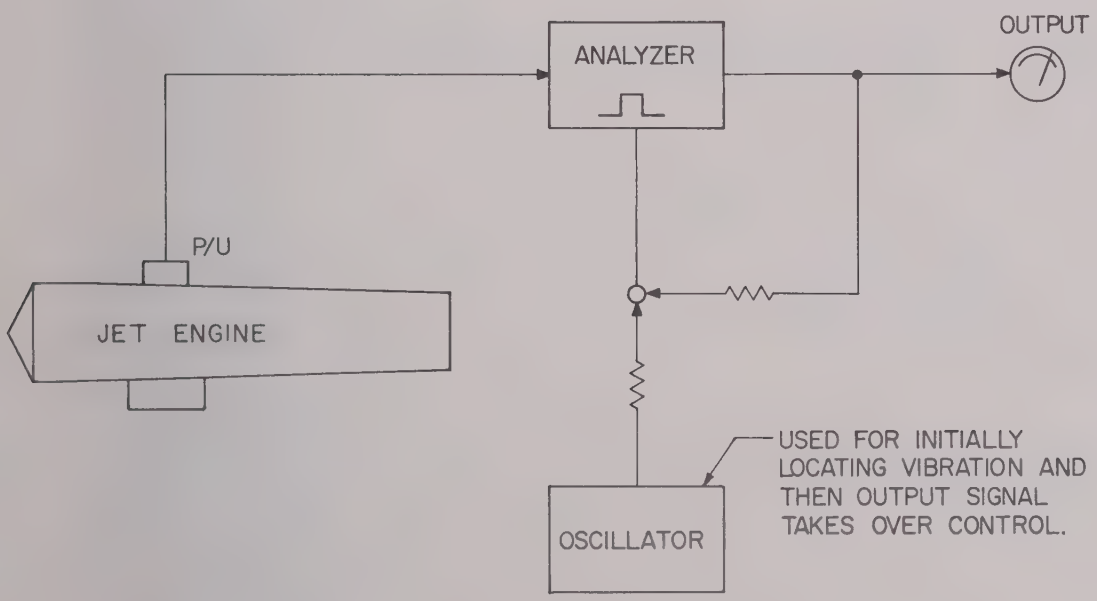
Purpose: To determine sources and magnitudes of the vibration from a machine to facilitate repair, engineering data, and/or preventive maintenance programs. The equipment with modification would be quite suitable for airborne use, and can be programmed from external sources for automatic checkout systems.



Assume the ratio of the tachometer frequency to the N_1 rotor is 2 or $\frac{\text{Rotor}}{\text{Tach}} = 2$

By multiplying the tach frequency continuously by two, the output from the frequency multiplier will be the rotor's frequency which tunes the filter to pass only the vibration amplitudes and frequency of the rotor. As the engine accelerates, the output of the frequency multiplier is still the rotor frequency and continuously tunes the filter to pass only vibration amplitudes at the rotor frequency.

Note: The tachometer frequency is a function of engine R.P.M. and since the tachometer is geared to the prime rotating shafts, the R.P.M. of the other shafts are related to the tachometer frequency by a constant, or a particular shaft frequency F_s = KX tach frequency. The frequency multiplier is for the purpose of generating tuning signals for the frequency tuned bandpass filter. The output from an engine mounted vibration pickup will contain fundamental frequencies and amplitudes due to the vibrations of the various rotating parts. The analyzer is used to separate and measure these amplitudes and frequencies; and by relating a particular vibration level to a given "Tach Ratio", the vibration level of a particular shaft may be measured and tracked over its operating speed range.



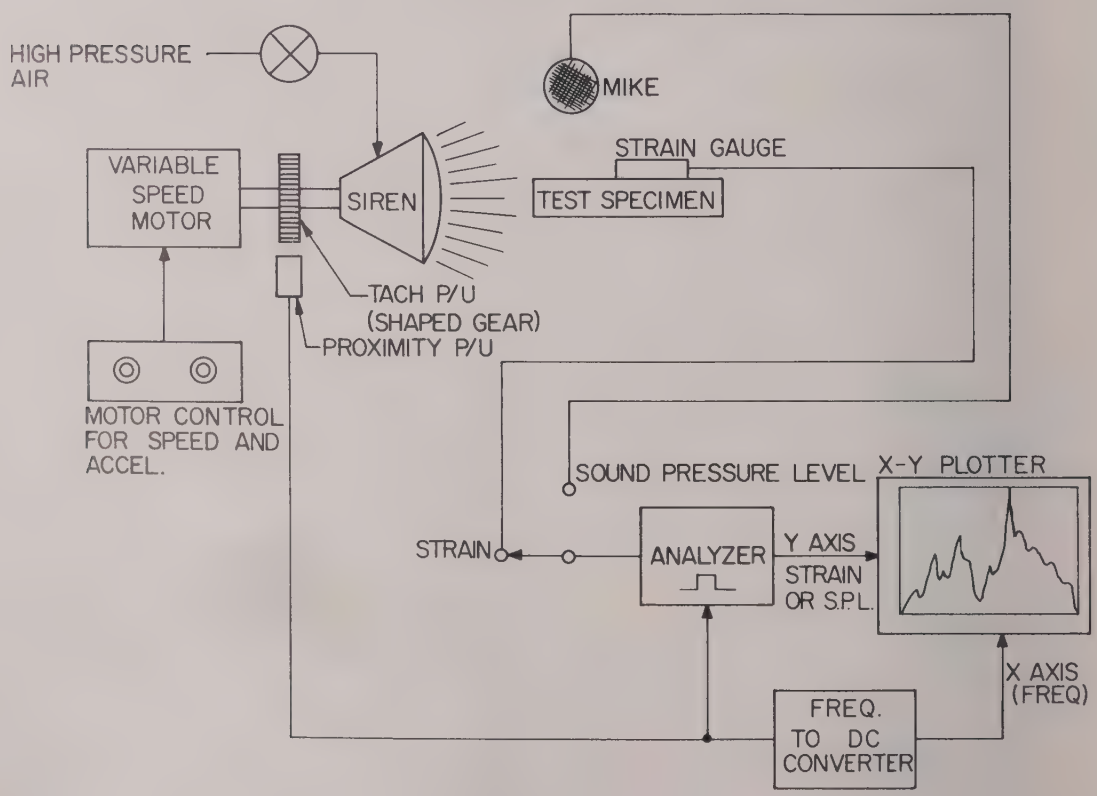
Another approach to tracking selected components of an engine would by by the use of the self-tracking characteristics of the instrument. This is a relatively new concept we have developed and has opened up many new methods of approach. When an output signal exists, the instrument "locks on" the frequency and automatically tracks.

II. SONIC TESTING

Sonic fatigue testing is a new and important field of testing. Its purpose is to determine the fatigue life of various materials and constructions in the presence of high intensity sound sources.

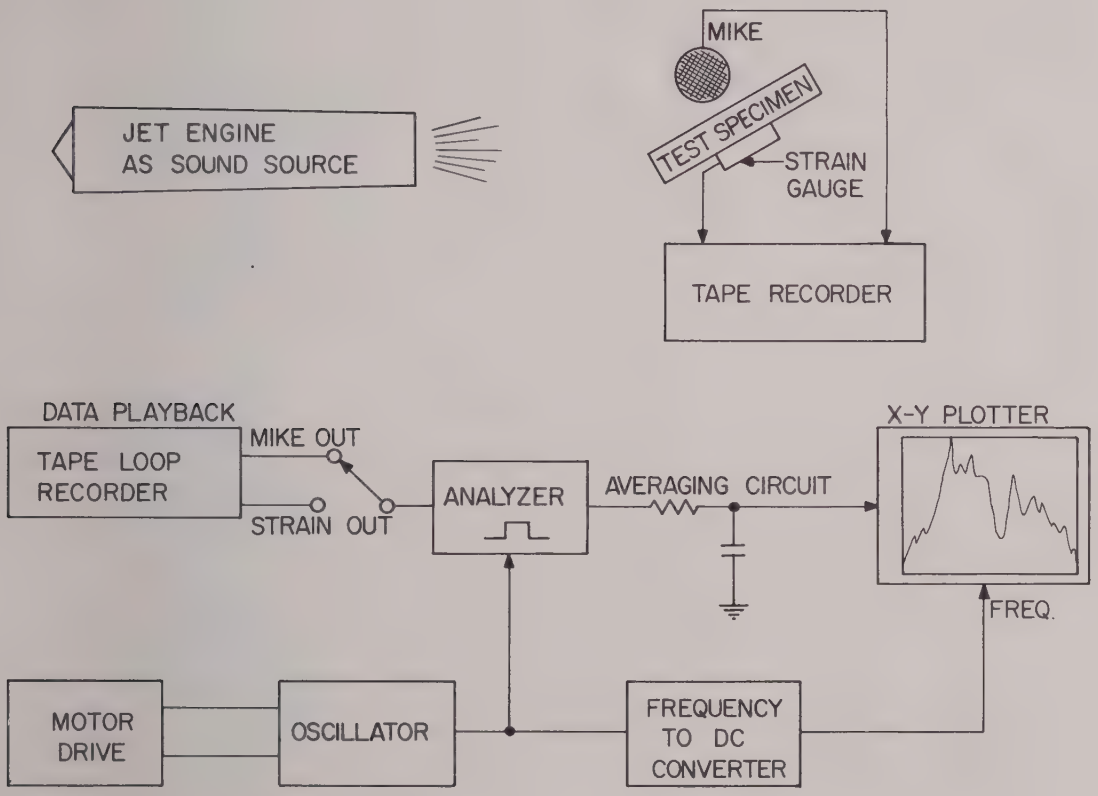
Two types of sound environments are used, i.e., Random and Sinussoidal.

1. Typical setup for sine wave testing:



PURPOSE OF ANALYZER: Due to large amounts of harmonic content in a siren, the analyzer is used to measure the fundamental driving sound pressure level and the fundamental sinusoidal response. If this were not used, errors in measurement would result in that the measuring instruments are calibrated in terms of a sine wave and sinusoidal signals should be used to evaluate response characteristics. The filter also eliminates multiple frequencies, or spurious responses from showing up on frequency response plots.

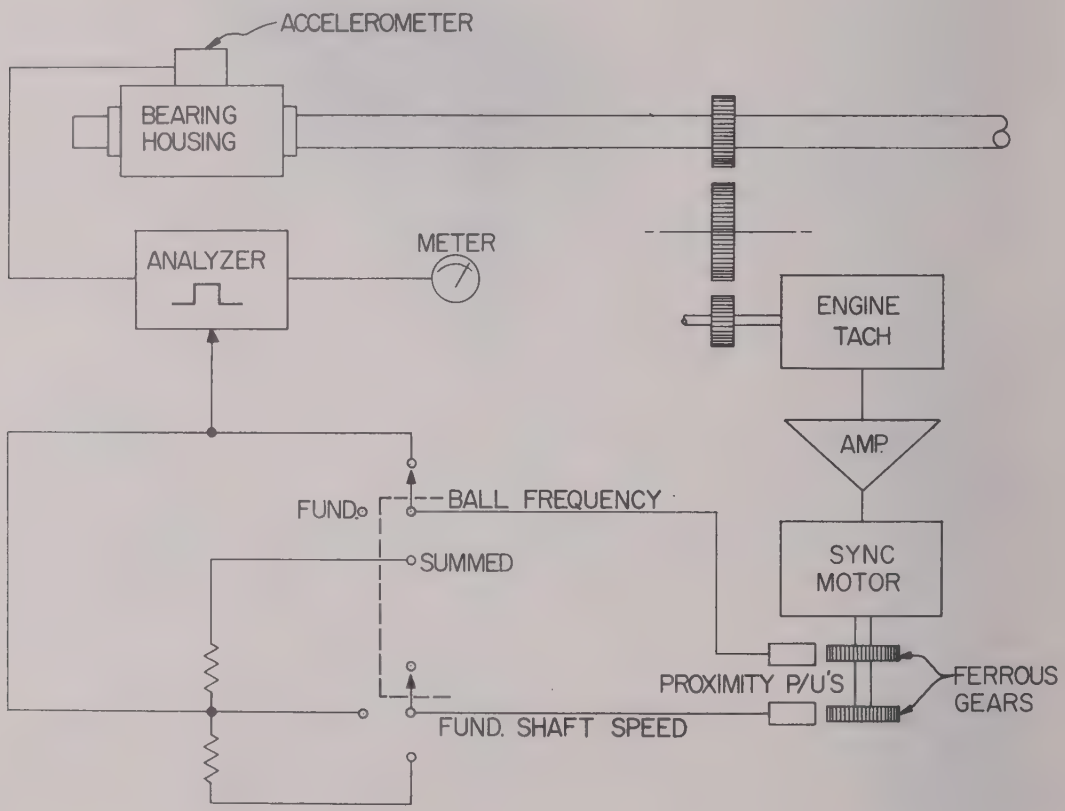
2. Setup for Random testing:



In this application the data is played back from a tape loop recorder. By slowly sweeping the frequency of an oscillator over the desired frequency, plots of average sound pressure, strain, etc., may be obtained.

III. BEARING ANALYSIS

Information gathered during our sales demonstrations indicate that the airlines, engine manufacturers and Air Force are interested in a technique of detecting defective bearings before actual failure occurs. The present technique used by the customer is the measurement of bearing temperatures. This has been found to be very unreliable due to the cooling oil used. The Frequency Tuned Band-Pass Filter provides a natural method for monitoring and detecting these occurrences.



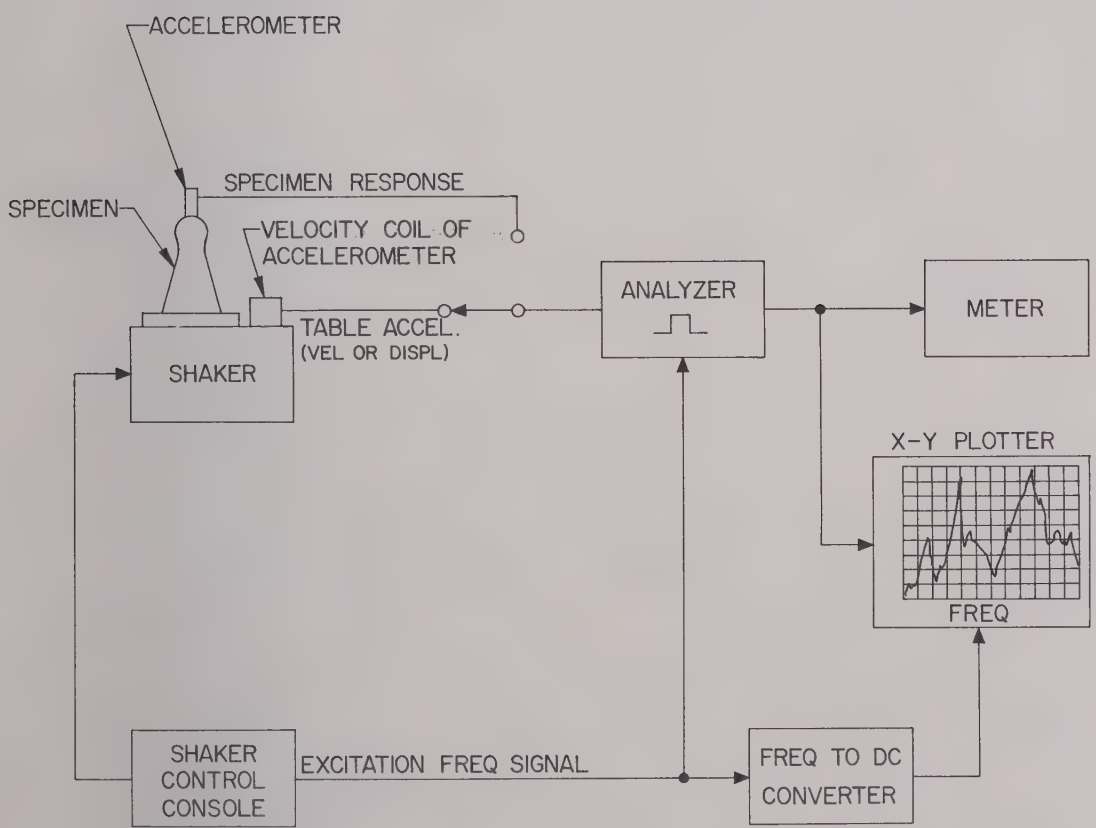
By tuning the analyzer to the ball and fundamental frequencies, the analyzer will indicate the algebraic sum of the two responses and when this exceeds a predetermined level the operator may select the ball or race frequency to determine which one is vibrating excessively.

IV. SHAKER TABLE VIBRATION MONITORING AND CONTROL SYSTEMS

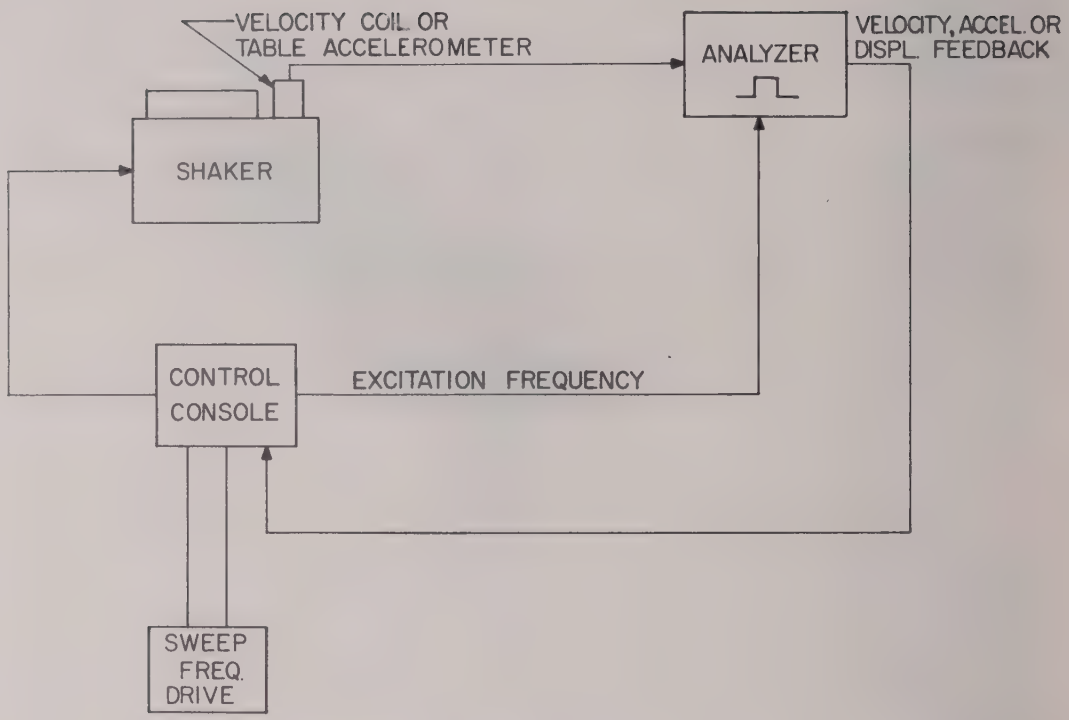
Reference: Attached article by Donald Wrisley entitled: Some Effects of Acceleration Waveform Distortion in Sinusoidal Vibration Testing. Reprinted from Test Engineering Magazine.

PURPOSE OF ANALYZER: To provide measurement of the fundamental acceleration levels and responses of test specimens to remove the effects of waveform distortions from meter and feedback circuits; to apply feedback control voltages for controlling acceleration, velocity or displacement levels of swept shaker systems.

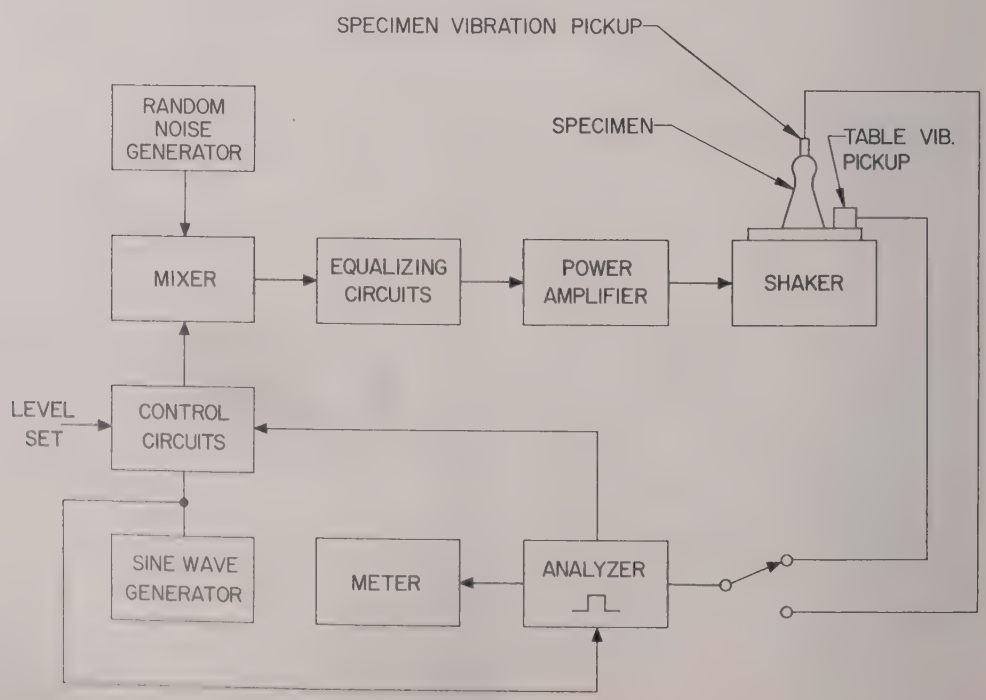
Monitoring and Measurement



Feedback Control



Sine Random Mixed Shaker Systems



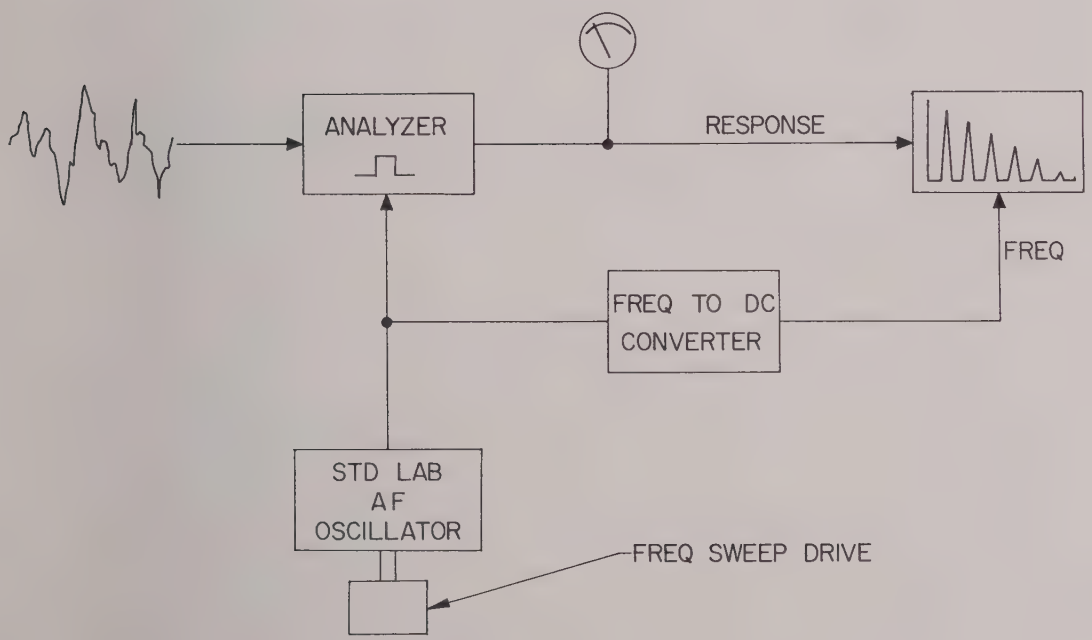
PURPOSE OF ANALYZER: To measure response of shaker and/or specimen to a sine wave component in the presence of random signals and/or for feedback control of sine component applied to the shaker.

V. HARMONIC WAVE ANALYSIS

Purpose: To perform Fourier analysis of periodic wave forms; to measure characteristics of transmission lines, distortion components, etc.

Advantages: Our analyzer has superior stability over conventional types of analyzers, thus gives more reliable and accurate results. Meter display or X-Y plots may be obtained. Also by utilizing the self-tracking feature, the system would "lock" onto the frequency component making the unit much easier to use and tune.

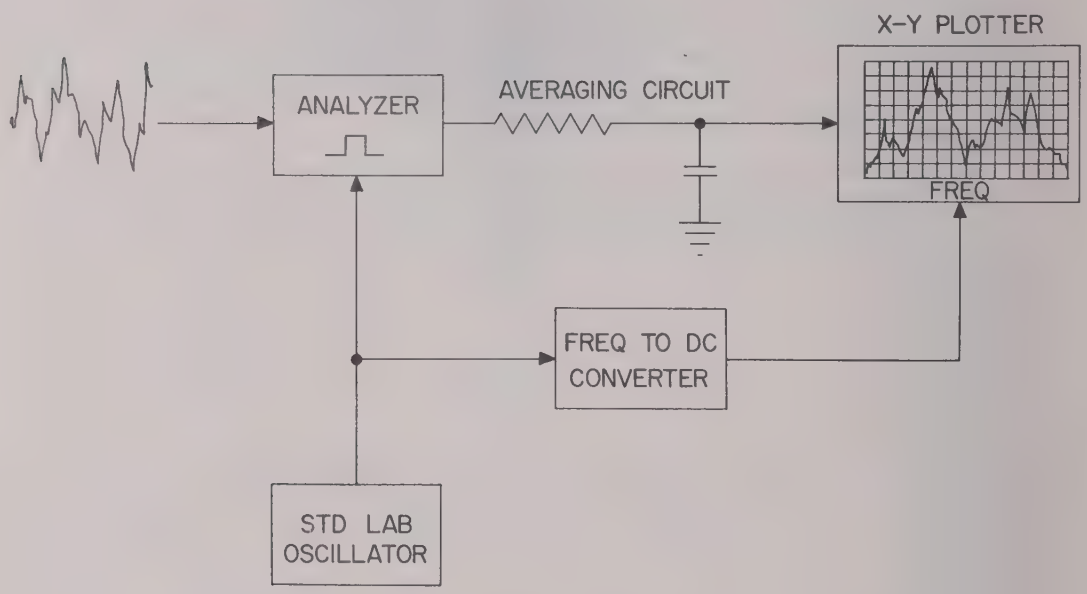
Our analyzer eliminates the need for the critical, expensive high frequency tunable local oscillator used in conventional analyzers, and provides much more operational versatility.



VI. RANDOM WAVE ANALYSIS

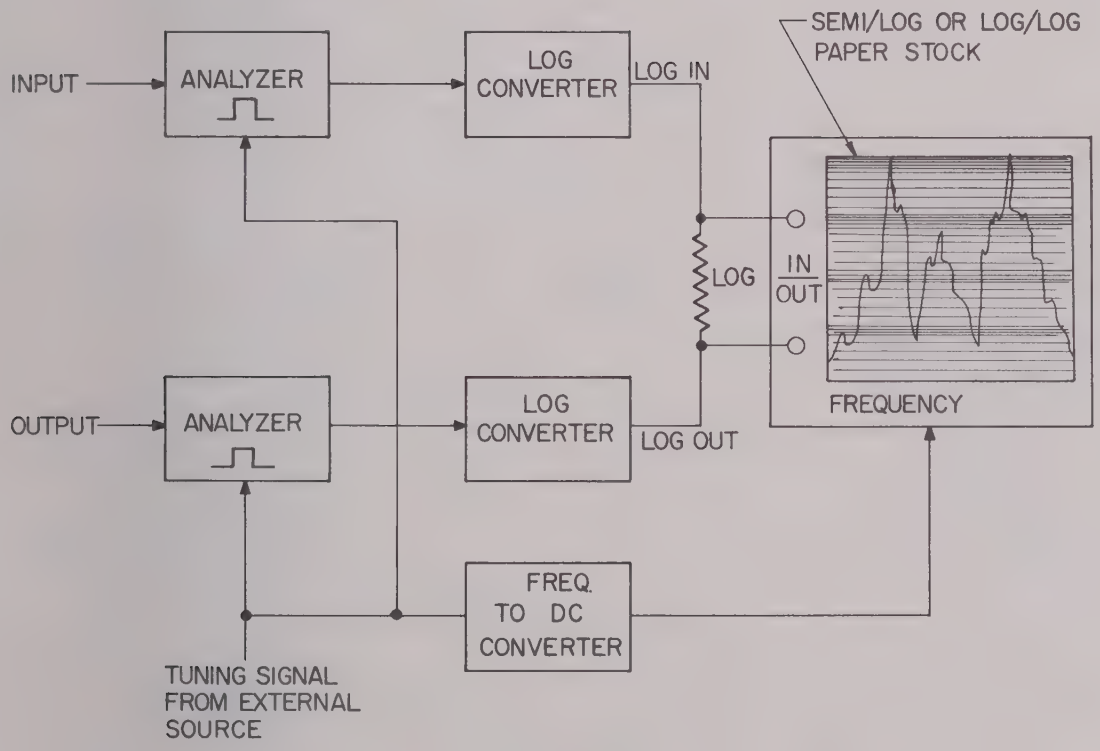
Purpose: To provide data on spectral density or average g/cycle vs. frequency for missiles, gust analysis, Random vibration tests, environmental determination.

Advantages: This instrument provides superior stability and application versatility, plus easily expanded into "comb" filter arrangements.



VII. TRANSMISSIBILITY AND MECHANICAL IMPEDANCE

Purpose: To obtain normalized plots of input/output or fundamental driving/response functions of two signals in a high noise environment. May be used for shake table analysis, mechanical impedance, flutter testing, sonic testing, and any other application where this type of data is being obtained.

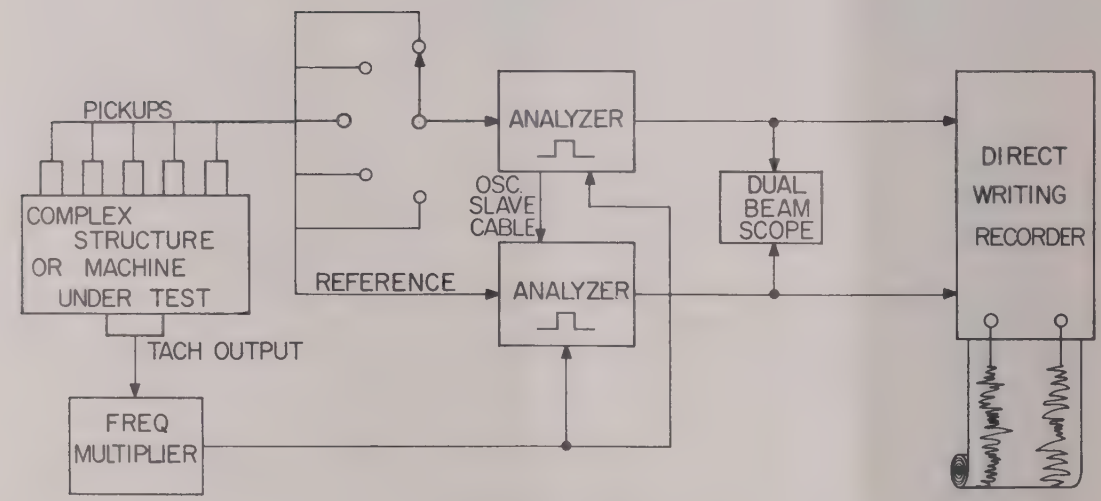


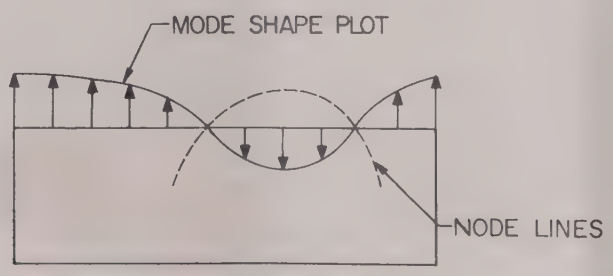
VIII. (Tentative)

MULTI-FILTER INSTALLATIONS for mode shape plotting in noise environments. (Mode shapes are plots of relative amplitudes and phasing.)

For: Jet engines, motors, turbines, aircraft, etc.

Advantages: Our instrument makes obtaining this type of data practical.





IX. FLUTTER TESTING

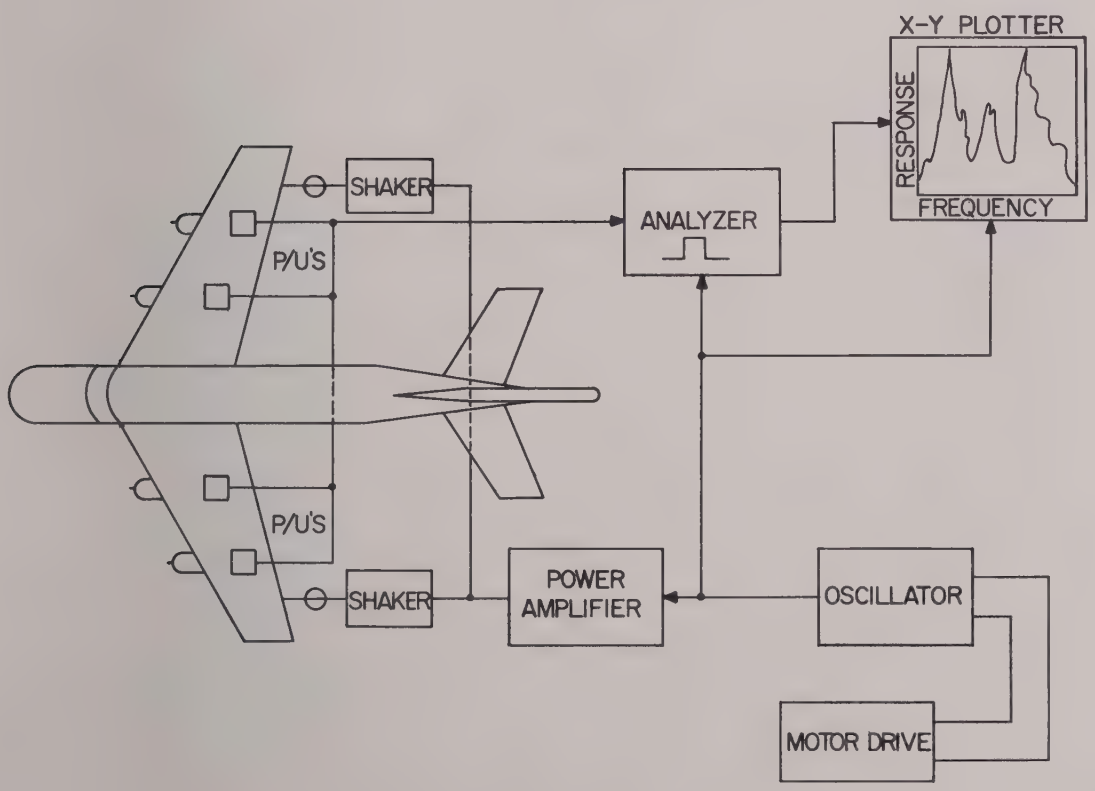
In flutter testing there are usually several types of vibration tests and test programs performed before an experimental aircraft is certified.

These tests usually include ground vibration tests of dynamic similar models, followed by wind tunnel tests to determine the models margin of stability. (This includes control surfaces and major air foils.)

When the first prototype aircraft is completed, a ground vibration test is then performed to compare computed modes with airplane and model modes. Following the aircraft ground vibration tests, flight flutter tests are performed to establish the aircrafts margin of stability. Each phase of the test program presents its own particular problems and many different test techniques are used. Certain missile tests are conducted along similar lines.

How the Analyzer is applied to each phase is described below:

A. Model Ground Vibration Tests.



The analyzer can be used when making automatic plots of frequency versus response to eliminate effects noisy test locations and multiple frequencies from showing up on the frequency versus response plots.

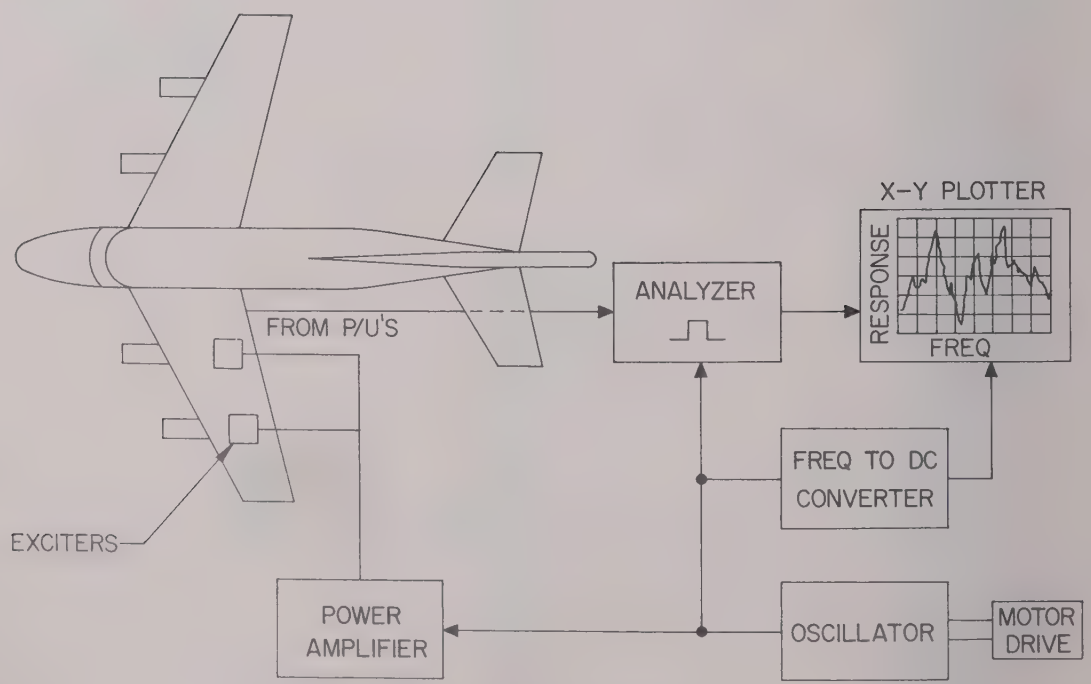
The purpose of the plots are to define the frequency location of the models natural modes of vibration.

B. Model Wind Tunnel Tests

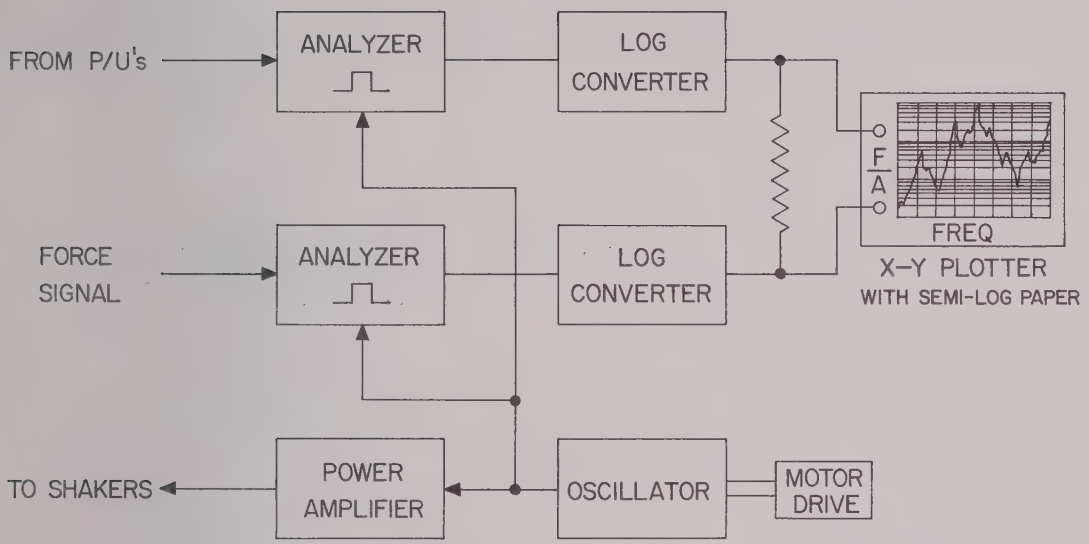
There are various techniques for conducting wind tunnel tests. I will describe three (3) types:

1. Models with sinusoidal excitation
2. Models that are excited by a step function (by "jerk" wire)
3. Models subjected to random excitations

1. (a) Sinusoidal Excitation



(b) Sinusoidal excitation measuring input force/amplitude.

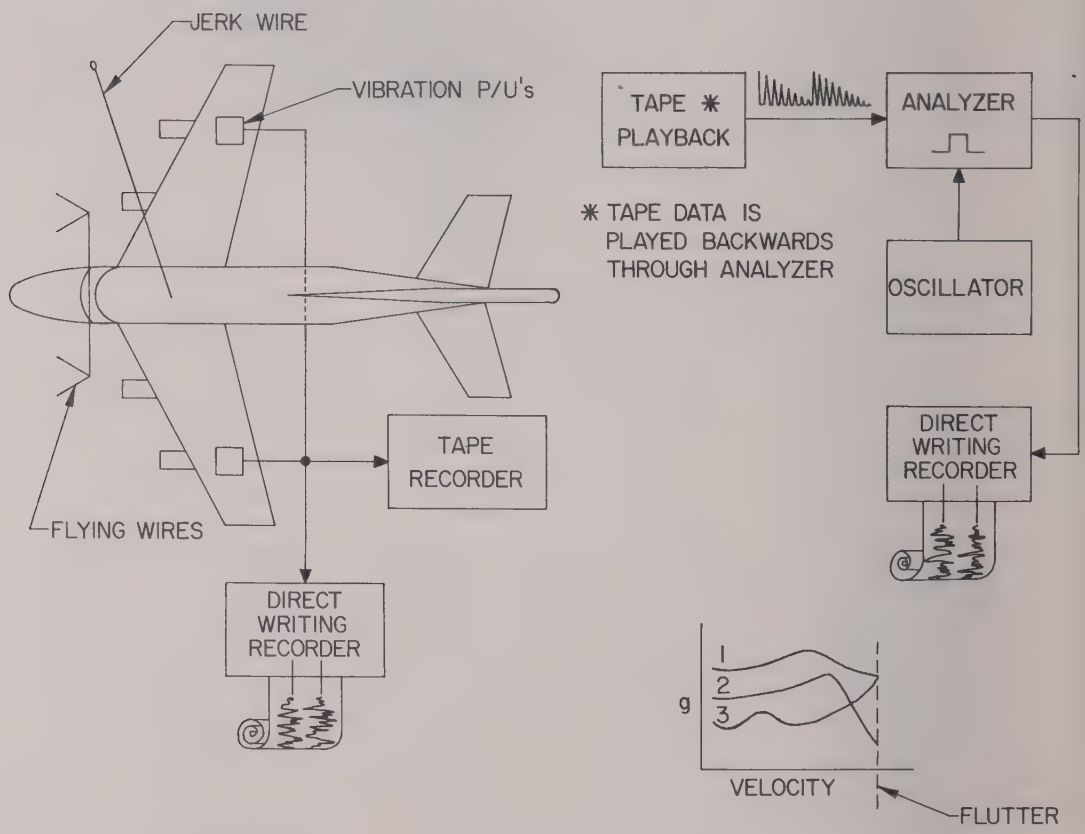


The advantage of the F/A plot is that obtaining one plot at a given test velocity provides all the necessary data at that velocity. By plotting F/A of each mode vs. test velocity flutter can be predicted because as flutter is approached $\frac{F}{A} \rightarrow 0$.

2. Jerk Wire Excitation

With this method it is very often difficult to get good data. Data reduction cannot easily be made on an "on line" basis.

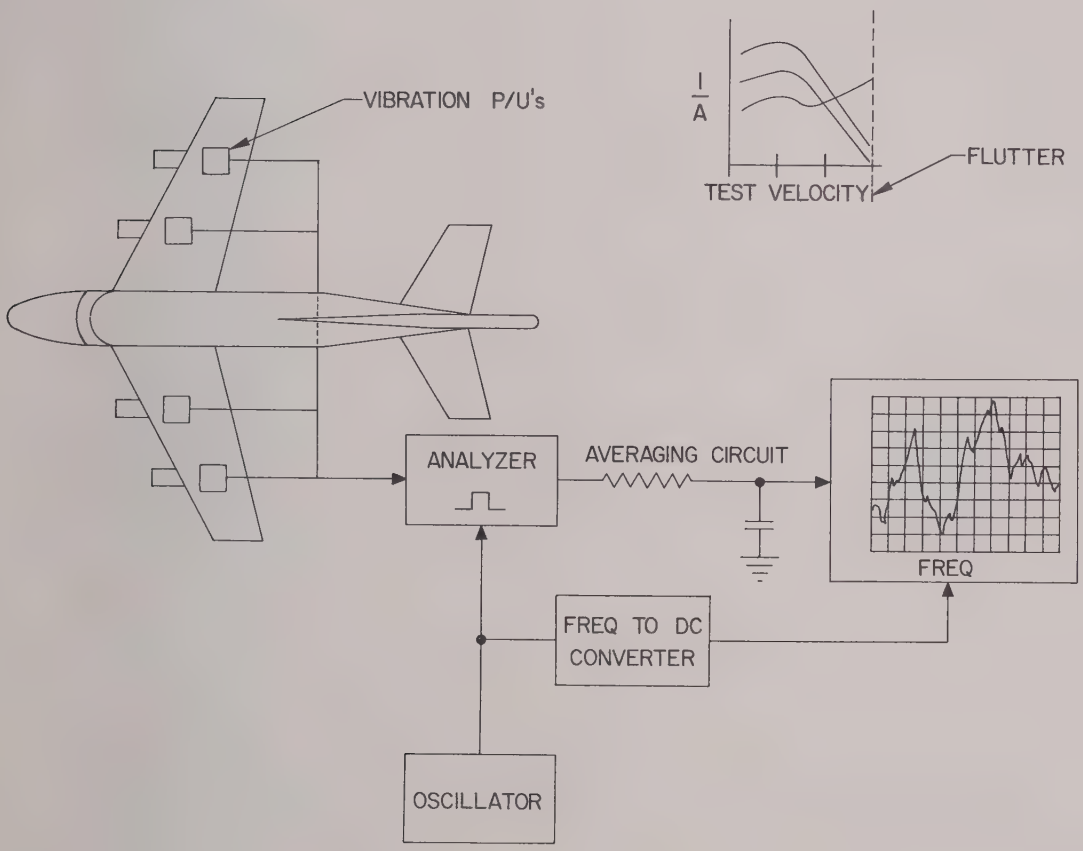
The technique is that of plotting Logarithmic Decrement ("g") versus test velocity for each natural mode. To obtain this data a wire attached to the model is "jerked" and a recording of decays made.



Filter characteristics are quite important in this application. The analyzer separates the frequencies of the various modes that are excited and allows each modes damping to be measured.

3. Random Excitation

Some wind tunnels exhibit rather high turbulence levels that can be used to provide adequate excitation for some model tests. It is assumed that the power spectral density of the turbulence is some function of velocity and is repeatable between runs. The analyzer is used to analyze the models average random response versus frequency at various tunnel speeds to predict flutter.

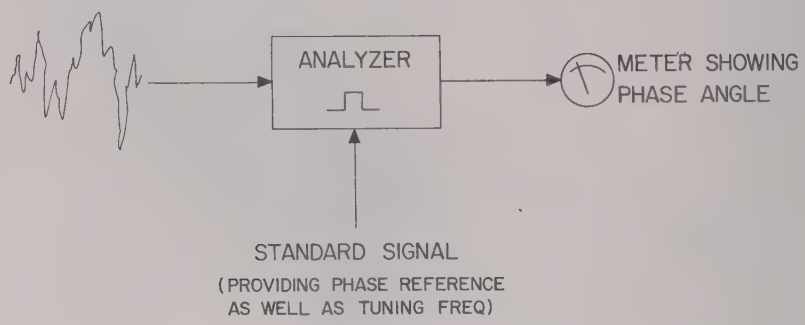


TYPICAL FOR RANDOM EXCITATION

Fullscale aircraft are usually tested with some form of sinusoidal excitation and the data telemetered or reduced on board depending upon available space in the aircraft. The methods outlined for model tests using sinusoidal exciters or the "jerk wire" method (using control system pulsing) are also used.

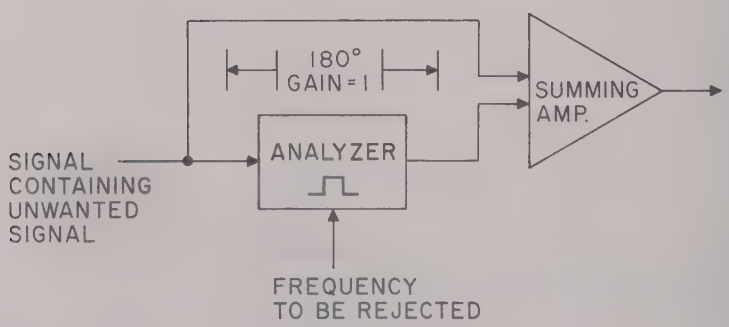
X. PHASE MEASUREMENTS

Slight modifications will enable phase measurements of a noisy signal to that of a standard signal. Two (2) analyzers may be employed to obtain phasing of two noisy signals.



XI. FREQUENCY TUNED BAND REJECT OR "NOTCH" FILTER

Utilizing the demodulated output of the analyzer a phase shift of 180° and unity gain through the analyzer may be established to allow rejection of the signal to which the unit is tuned.



REPRINTED FROM TEST ENGINEERING MAGAZINE

SOME EFFECTS OF ACCELERATION WAVEFORM DISTORTION IN SINUSOIDAL VIBRATION TESTING

By: Donald L. Wrisley
Wrisley Engineering, Inc.
(Winchester, Mass.)

THE PRESENCE OF DISTORTION in the acceleration waveform at some frequencies in the range encompassed by most vibration test specifications is well known. Most frequently, this is the result of small amounts of harmonics in the output of the power supply being amplified by "High Q" mechanical resonances in the moving system--very often the fundamental axis resonant mode of the shaker armature. (Although serious distortion is sometimes the result of shaker body resonances and of non-linear loads.)

For most modern shakers with force outputs above 1,000 pounds, the fundamental axial mode occurs at some frequency between 1,500 cps and 5,000 cps for no load, and of course at progressively lower frequencies as table loading is increased. It is readily evident that 3rd harmonic distortion of fundamentals between 500 cps and 2000 cps present in the power supply output can excite these mechanical resonances. And because these resonances are very lightly damped, the 1/2% to 3% distortion present in the best of amplifiers can be magnified to the extent that acceleration waveforms with 20%, 50% or greater harmonic distortion are not uncommon. Figure 1 shows some typical waveforms containing 3rd harmonic distortion of these orders of magnitude.

TABLE 1. True Peak Acceleration (G) for 10 G Peak Acceleration Indicated on Typical Averaging Meter

Amplitude of 3rd Harmonic as a % of Fundamental	True Peak Acceleration, G				
	0°*	30°*	60°*	90°*	180°*
0	10	10	10	10	10
10	8.7	9.2	9.8	10.4	11.4
20	8.2	9.0	10.5	11.1	12.2
50	9.2	10.5	12.1	13.9	18.0

*Angle in degrees by which 3rd harmonic leads fundamental.

Let's take a look at what this means in relation to monitoring and automatic control of acceleration level.

First of all, most vibration systems include a monitor or vibration meter. This is usually a vacuum tube voltmeter which provides readout on a conventional rectifier type meter--an averaging device. The scale reads in terms of peak acceleration, which, for a pure sine wave, bears a known relationship to the average value of the acceleration waveform. The simple, known relationship is destroyed, however, in the case of a waveform with even a modest amount of harmonic content. To complicate things further, the phase of the harmonic relative to the fundamental drastically affects the relative magnitudes of peak and average values of the waveform. Table I shows the true value of peak acceleration for the case where INDICATED peak acceleration is held constant using an averaging meter calibrated in terms of peak. Shown are the effects of phase as well as magnitude of 3rd harmonic distortion.

From Table I, it is apparent that indicated acceleration under these circumstances is quite unreliable, and the true peak acceleration can be lower or dangerously higher than our meter would have us believe. For example, in the worst case tabulated, the true peak acceleration is almost twice that indicated.

Next, let's look at this in terms of servo controlled, swept sine tests. If the servo system samples a feedback signal that is proportional to the average value of acceleration (and some do), then we have a situation like that above, and our test specimen may be subjected to peak accelerations far greater than called for. If our meter is the averaging type, we will not see this. If our meter is a true peak reading meter, it will indicate this and the impression may be that the servo system is not holding level properly. On the other hand, if the servo system operates on a feedback signal proportional to the peak value of acceleration (and again some do), we have a slightly different situation. We are now perhaps more nearly meeting the intent of the specification (most of which are written in terms of peak acceleration), and we are certainly treating our specimen more gently. But, if our meter is the averaging type, we must recognize that again it is not going to give a true indication of the peak value of acceleration. This is shown in Table II, which gives the value of peak acceleration that would be indicated by the averaging meter when the true peak acceleration is held constant. Again, the effect of phase relationship between fundamental and harmonic is given for three levels of 3rd harmonic distortion.

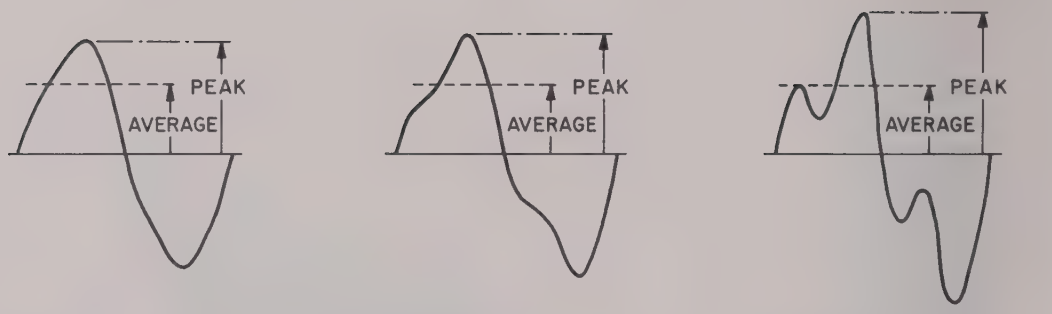
TABLE II. Peak Acceleration as Indicated by Averaging Meter for 10 G True Peak Acceleration

Amplitude of 3rd Harmonic as a % of Fundamental	Indicated Peak Acceleration, G				
	0°*	30°*	60°*	90°*	180°*
0	10	10	10	10	10
10	11.5	10.9	10.2	9.6	8.8
20	12.2	11.1	9.9	9.0	7.8
50	10.8	9.5	8.3	7.2	5.6

*Angle in degrees by which 3rd harmonic leads fundamental.

Further, when we remember that the phase of the mechanical response changes as we go through a resonance, we can expect our meter to perhaps read both low and high within a very narrow frequency band as the fundamental passes from below to above 1/3 the mechanical resonant frequency.

In view of the terminology of most specifications, it would seem desirable for the vibration equipment manufacturer to use feedback proportional to peak value of the acceleration waveform and to provide a true peak reading meter on which to monitor acceleration level. In addition, the use of a cathode ray oscilloscope to continuously observe acceleration waveforms obviously recommends itself. However, our purpose here has been more to present this fact of life and the nature of things to the TEST ENGINEER who has the problem now! We may not like it, but understanding does make it easier to live with, and may make acceptable a test which otherwise might be ruled unacceptable. END

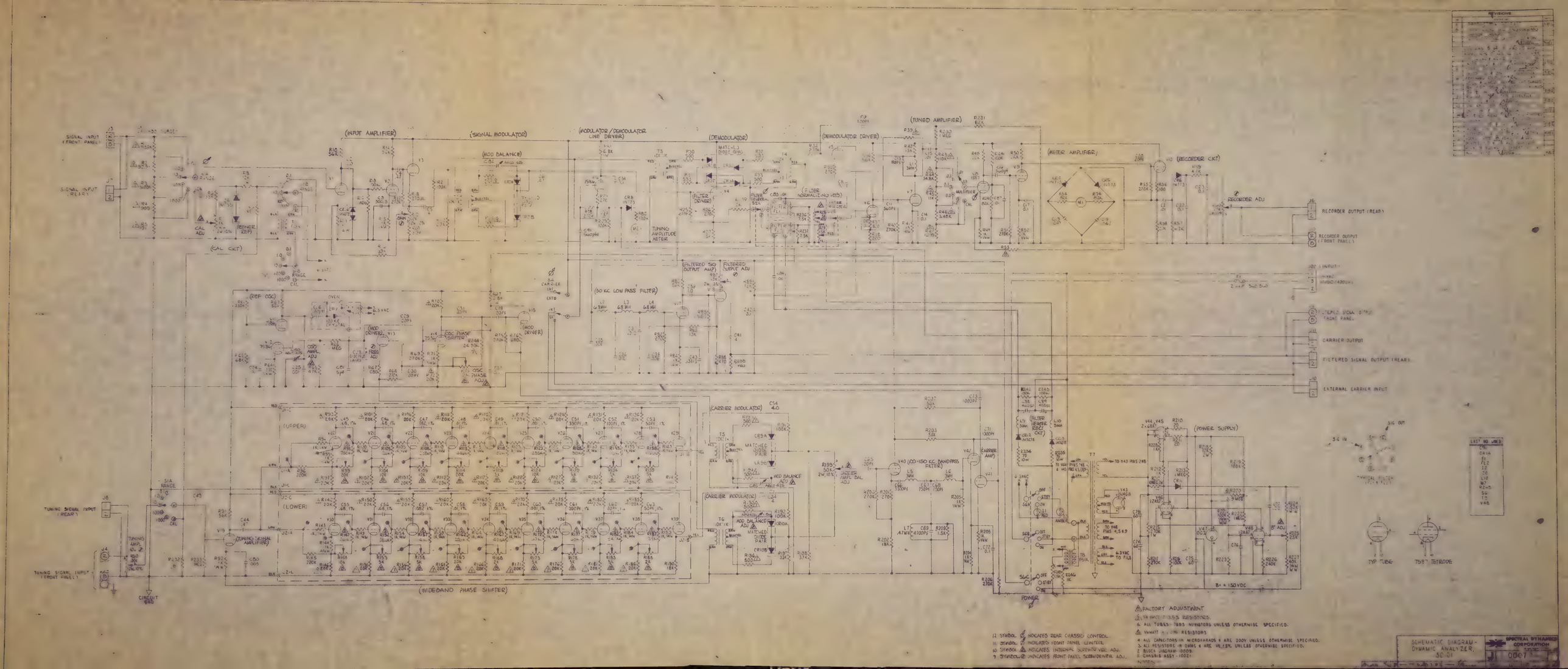


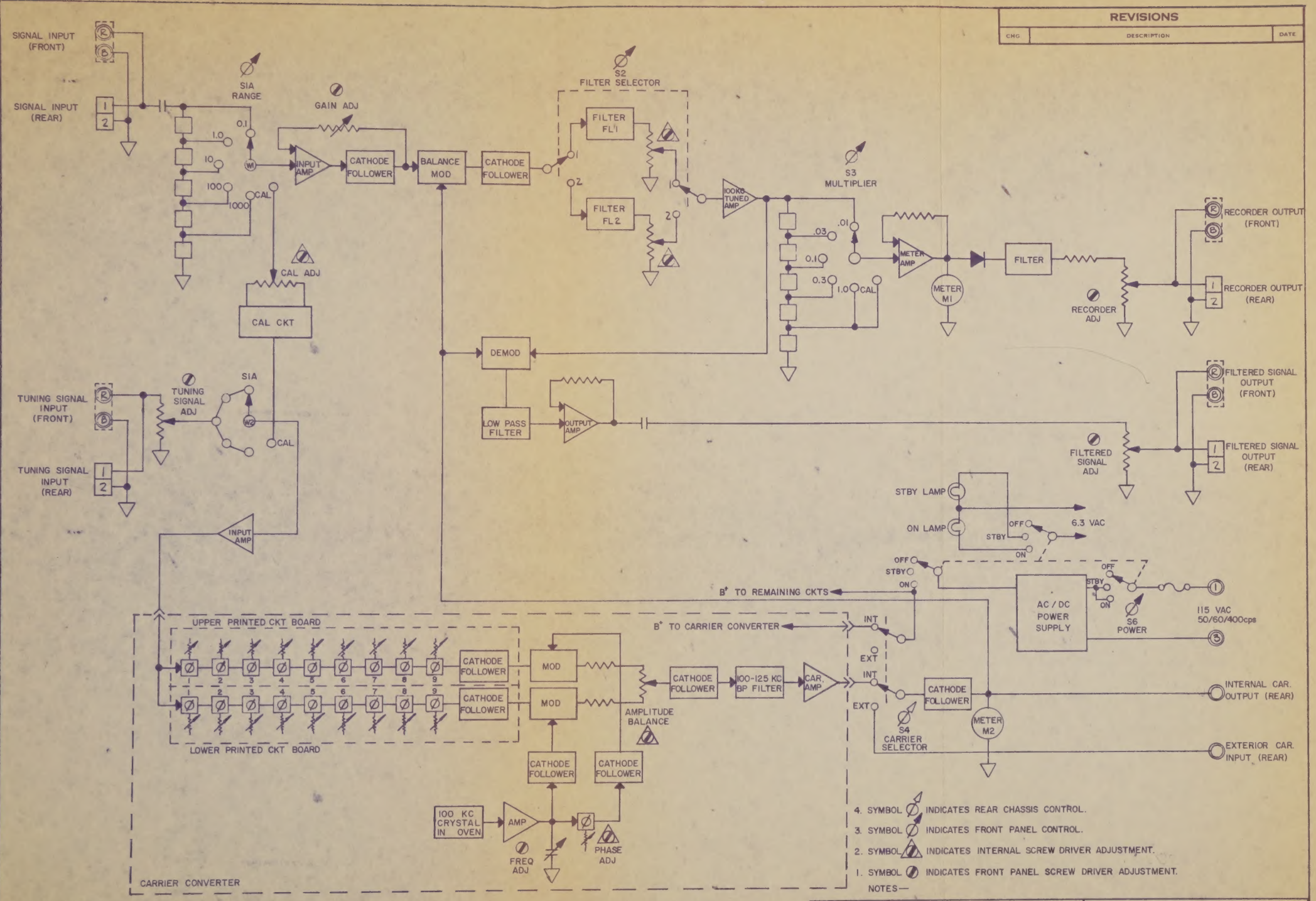
AMPLITUDE OF 3RD HARMONIC - 10% OF AMPLITUDE OF FUNDAMENTAL PHASE -- 90° LEADING

AMPLITUDE OF 3RD HARMONIC - 30% OF AMPLITUDE OF FUNDAMENTAL PHASE -- 90° LEADING

AMPLITUDE OF 3RD HARMONIC - 50% OF AMPLITUDE OF FUNDAMENTAL PHASE -- 90° LEADING

Figure 1. Typical Acceleration Waveforms Containing 3rd Harmonic Distortion. Note that for This Particular Phase Relationship Average Value is Unaffected by Amount of Harmonic While Peak Value is Drastically Changed.


REVISIONS
SIGNAL INPUT (FRONT PANEL)
SIGNAL INPUT (REAR)
(INPUT AMPLIFIER)
(SIGNAL MODULATOR)
(MODULATOR/DEMODULATOR LINE DRIVER)
(DEMODULATOR)
(DEMODULATOR DRIVER)
(TUNED AMPLIFIER)
(METER AMPLIFIER)
(RECORDER CKT)
RECORDER ADJ
RECORDER OUTPUT (REAR)
RECORDER OUTPUT (FRONT PANEL)
(CAL CKT)
(REF OSC)
(30 KC LOW PASS FILTER)
(FILTERED SIG OUTPUT AMP)
FILTERED OUTPUT ADJ
CARRIER INPUT
CARRIER OUTPUT
FILTERED SIGNAL OUTPUT (REAR)
EXTERNAL CARRIER INPUT
(UPPER)
(LOWER)
(WIDEBAND PHASE SHIFTER)
(CARRIER MODULATOR)
(CARRIER AMPLIFIER)
(POWER SUPPLY)
TUNING SIGNAL INPUT (REAR)
TUNING SIGNAL INPUT (FRONT PANEL)
CIRCUIT GND
B+ = 150 VDC
TYP TUBE
7591 TETRODE
FACTORY ADJUSTMENT
SCHEMATIC DIAGRAM - DYNAMIC ANALYZER, SD-1
SPECTRAL DYNAMICS CORPORATION
0007



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BLOCK DIAGRAM— DYNAMIC ANALYZER, MODEL SD101

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